ENERGY STAR® Performance Ratings
Technical Methodology for Hospital (General Medical and Surgical)

This document presents specific details on the EPA's analytical result and rating methodology for Hospital. For background on the technical approach to development of the Energy Performance Ratings, refer to *Energy Performance Ratings – Technical Methodology* (http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf).

Model Release Date[1]

Most Recent Update: November 2011
Original Release Date: November 2001

Portfolio Manager Definition

Hospital applies to a general medical and surgical hospital (including critical access hospitals and children's hospitals) that is either a stand-alone building or a campus of buildings. These facilities provide acute care services intended to treat patients for short periods of time, including emergency medical care, physician's office services, diagnostic care, ambulatory care, surgical care, and limited specialty services such as rehabilitation and cancer care.

The definition of Hospital accounts for all space types that are located within the Hospital building/campus, such as medical offices, administrative offices, and skilled nursing. The total floor area should include the aggregate floor area of all buildings on the campus as well as all supporting functions such as: stairways, connecting corridors between buildings, medical offices, exam rooms, laboratories, lobbies, atria, cafeterias, storage areas, elevator shafts, and any space affiliated with emergency medical care, or diagnostic care.

More than 50% of the gross floor area of all buildings must be used for general medical and surgical services AND more than 50% of the licensed beds must provide acute care services. Properties that use more than 50% of the gross floor area for long-term care, skilled nursing, specialty care, and/or ambulatory surgical centers or that have less than 50% of their beds licensed for acute care services are not considered eligible hospitals under this definition.

Ineligible healthcare spaces:

- Long-term care hospitals that are certified as acute care hospitals are not eligible because they provide patients with acute care for extended inpatient stays, defined by federal statute as an average of 25 days or more.
- Ambulatory surgical centers, specialty hospitals, and other types of long-term care facilities should benchmark under the "Other" space type category.

[1] Periodic updates to the model occur to reflect the most current available market data. The original model was developed using data from the Electric Power Research Institute's (EPRI) Energy Benchmarking Survey completed in 1997. The most current update of November 2011 reflects a survey conducted in 2010 by the American Society for Healthcare Engineering.

Reference Data

The Hospital regression model is based on data from an industry survey conducted by the American Society for Healthcare Engineering (ASHE), a personal membership society of the American Hospital Association (AHA). EPA relies on publicly available external data sets to develop rating models where feasible, but a sufficiently robust set of hospital energy consumption information was not available. The industry-based survey was designed to account for the variation in service found in hospital facilities and to take into consideration energy use in multi-building campus settings. Efforts were made to provide as large, diverse, and representative of a sample as possible. AHA includes nearly all of the hospitals in the U.S., and ASHE members work in approximately 80% of the hospitals in the country. The survey was open to all interested participants, including non-members, and efforts were made by EPA, ASHE, and AHA to provide as large, diverse, and representative of a sample as possible.

Data Filters

Four types of filters are applied to define the peer group for comparison and to overcome any technical limitations in the data: Building Type Filters, EPA Program Filters, Data Limitation Filters, and Analytical Filters. A complete description of each of these categories is provided in Section V of the general technical description document: *Energy Performance Ratings – Technical Methodology*. **Table 1** presents a summary of each filter applied in the development of the Hospital model, the rationale behind the filter, and the resulting number of observations after the filter is applied. After all filters are applied, the remaining data set has 191 observations.

Table 1 Summary of Hospital Model Filters		
Condition for Including an Observation in the Analysis	**Rationale**	**Number Remaining**
Must have complete data for energy use and operating characteristics	EPA Program Filter – Complete data is necessary for analysis	232
Hospital type must be General Medical and Surgical (including Critical Access Hospitals and Children's Hospitals).	Building Type Filter – In order to be defined as Hospital, the Hospital type must be General Medical and Surgical (including Critical Access Hospitals and Children's Hospitals).[2]	208
If Parking Energy is reported with metered data, the size of all parking structures (enclosed and not enclosed parking) cannot exceed building size.	EPA Program Filter – If the combined square foot of parking structures exceeds the size of the hospital building then the overall structure is classified as parking, not Hospital. This is a standard policy in Portfolio Manager	205
If Parking Energy is reported with metered data, EPA's Estimated Parking Adjustment must be less than 50% of the actual source energy.	Analytical Filter – In order to perform an analysis of the building (not the parking), EPA estimates the energy use of the parking area[3]. If this estimation is 50% or more the actual source energy, it is determined that there is too much variability/error in the energy use.	205
Must have greater than 0.5 and less than 10 workers per 1,000 square foot	Analytical Filter – Values determined to be data entry errors or statistical outliers.	201
Must have less than 0.02 MRI Machines per 1,000 square foot	Analytical Filter – Values determined to be data entry errors or statistical outliers.	200
Must have less than 1.8 Staffed Beds[4] per 1,000 square foot	Analytical Filter – Values determined to be data entry errors or statistical outliers.	198
Must have floor area less than 2 million square feet	Analytical Filter – Values determined to be data entry errors or statistical outliers.	194
Must have Source EUI[5] greater than 100 kBtu/ft^2 and less than 1000 kBtu/ft^2	Analytical Filter – Values determined to be data entry errors or statistical outliers.	**191**

Survey Weights

Analysis of the Hospital survey data showed that one company contributed a large percentage (>30%) of the facilities in the data set. Additionally, the survey included a disproportionately large number of facilities from certain regions of the country, particularly from Texas and Florida. Therefore, rather than being a complete random sample of the population, the survey can be viewed as a stratified random sample, with multiple groups of respondents. In order to

[2] Hospital type is defined as the space type that represents more than 50% of the floor area, or the space type that represents the largest floor area, if no one space type is more than 50%.

[3] For more information on the methodology used for estimation, refer to the standard Portfolio Manager technical description for Parking, available at: http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager_model_tech_desc

[4] Staffed Beds were defined as beds set up and staffed for use. This value may differ from licensed beds.

[5] Source EUI refers to the EUI after parking and pool energy estimates have been removed to isolate the EUI for the Hospital space.

properly account for this stratification, survey sample weights were constructed to reflect the each. Observations were weighted by two categories. The first category was ownership by either the single large company or a company not affiliated with the large company. The second category was geographical region defined by the Census Regions and Divisions. Within each group, the weight of an individual observation was computed as:

Observation Weight = Total Size of Population in Group/Number of Responses in Group

The Total Size of Population in Group was obtained through regional market data supplied by AHA and market research on the company that contributed a large percentage of the observations. The Number of Responses in Group was counted from the complete set of 208 General and Medical Surgical hospitals in the survey.

Dependent Variable

The dependent variable in the Hospital analysis is source energy use intensity (source EUI). Source EUI is equal to the total source energy use of the facility divided by the gross floor area. By setting source EUI as the dependent variable, the regressions analyze the key drivers of source EUI – those factors that explain the variation in source energy per square foot in a Hospital.

Independent Variables

General Overview:

The Hospital survey data contains numerous building operation questions that EPA identified as potentially important for Hospitals. Based on a review of the available variables in the survey, in accordance with the EPA criteria for inclusion[6], EPA analyzed the following variables:

- Building Square Footage
- Number of Floors
- Total Number of Licensed Beds
- Total Number of Staffed Beds
- Number of Inpatient Days
- Number of Outpatient Visits
- Number of Full-time Equivalent (FTE) Workers
- Average Number of Hours per Week Occupied
- On-Site Laundry (Yes or No)
- Total Pounds of Laundry Processed Per Day
- On-Site Laboratory (Yes or No)
- On-Site Dietary Department (Yes or No)
- On-Site Tertiary Care Services (Yes or No)
- Number of MRI Machines

[6] For a complete explanation of these criteria, refer to *Energy Performance Ratings – Technical Methodology* (http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf).

- Number of CAT or CT Scans
- Number of PET Scans
- Number of Fixed X-ray Machines
- Number of Fluoroscopy Machines
- Number of Linear Accelerators
- Percentage of Square Footage designated as Operating Rooms
- Percentage of Square Footage designated as Delivery Rooms
- Percentage of Square Footage designated as Trauma Rooms
- Percentage of Square Footage designated as Total Procedure Rooms
- Percentage of Square Footage designated as Catheterization and Surgical XRay Rooms
- Heating Degree Days (base 65)
- Cooling Degree Days (base 65)

EPA performed extensive review on all of these operational characteristics. In addition to reviewing each characteristic individually, characteristics were reviewed in combination with each other (e.g., combinations of MRI, CT Scans, PET Scans, and other imaging equipment). As part of the analysis, some variables were reformatted to reflect the physical relationships of building components. For example, the number of FTE Workers is typically evaluated in a density format. The number of FTE workers *per square foot* (not the gross number of FTE workers) is expected to be correlated with the energy use per square foot. In addition, based on analytical results and residual plots, variables were examined using different transformations (such as the natural logarithm). The analysis consisted of multiple regression formulations. These analyses were structured to find the combination of statistically significant operating characteristics that explained the greatest amount of variance in the dependent variable: source EUI.

Based on the Hospital regression analysis, the following four characteristics were identified as key explanatory variables that can be used to estimate the expected average source EUI ($kBtu/ft^2$) in a Hospital:

- Number of full-time equivalent (FTE) workers per 1,000 square foot
- Number of staffed beds per 1,000 square foot
- Number of MRI Machines per 1,000 square foot
- Cooling degree days

Climate Variables (HDD and CDD)

Climate is one characteristic that was examined closely. EPA tested models with CDD and HDD, CDD only, and HDD only. Cooling Degree Days showed a positive correlation with total energy usage, which was expected. Heating Degree Days showed a negative correlation with total energy usage, which was not expected. It is believed that both observed relationships are a result of large internal cooling loads associated with hospitals. That is, because of heat given off by equipment, cooling overall is more of a driving force for hospitals. The positive correlation with CDD is intuitive, but the negative relationship with HDD results from an inverse relationship between HDD and CDD. Due to the high correlation between HDD and CDD, it was not possible to develop a strong model with statistically significant relationships for both weather variables. Models with CDD only showed stronger statistical performance and provided a more intuitive explanation for the relationship between weather and energy intensity.

Model Testing:
The regression permutations were tested by looking at regression statistics, residual plots, and energy performance ratings for all buildings in the sample. The average performance of buildings was examined across the entire survey population, in addition to subsets of the population to ensure no bias with respect to a specific type of hospital, a specific geographic location, a specific company, or any other parameters. Additionally, EPA performed a variety of test runs using existing Hospital buildings that have been entered into Portfolio Manager. The analysis provided a second level of confirmation that the final regression model produces robust results.

Regression Modeling Results

The final regression is a weighted ordinary least squares regression across the filtered data set of 191 observations. The dependent variable is source EUI. Each independent variable is centered relative to the mean value, presented in **Table 2**. The final model is presented in **Table 3**. All model variables are significant at the 98% confidence level or better, as shown by the significance levels (a p-level of less than 0.02 indicates 98% confidence). The model has an R^2 value of 0.2235, indicating that this model explains 22.35% of the variance in source EUI for Hospital buildings. Because the final model is structured with energy per square foot as the dependent variable, the explanatory power of square foot is not included in the R^2 value, thus this value appears artificially low. Re-computing the R^2 value in units of source energy[7], demonstrates that the model actually explains 87.02% of the variation of source energy of Hospital buildings. This is an excellent result for a statistically based energy model.

Detailed information on the ordinary least squares regression approach, the methodology for performing weather adjustments, and the independent variable centering technique is available in the technical document: *Energy Performance Ratings – Technical Methodology*.

Table 2
Descriptive Statistics for Variables in Final Regression Model

Variable	Full Name	Mean	Minimum	Maximum
Src_EUI	Source Energy Per Square Foot	484.8	109.9	976.0
FTEDen	Number of Full-time Equivalent (FTE) Workers per 1,000 ft^2	2.600	0.7646	6.498
BedDen	Number of Staffed Beds per 1,000 ft^2	0.4636	0.1106	1.426
MRIDen	Number of MRI Machines per 1,000 ft^2	0.0031	0.0000	0.0136
CDD	Cooling Degree Days	1392	0.0	4810

Note:
- *Statistics are computed over the filtered data set (n=191 observations) and weighted by the survey weights*
- *The mean values are used to center variables for the regression.*

[7] The R^2 value in Source Energy is calculated as: 1 – (Residual Variation of Y) / (Total Variation of Y). The residual variation is sum of (Actual Source Energy$_i$ – Predicted Source Energy$_i$)^2 across all observations. The Total variation of Y is the sum of (Actual Source Energy$_i$ – Mean Source Energy)^2 across all observations.

Table 3 Final Regression Modeling Results				
Dependent Variable		Source Energy Intensity (kBtu/ft^2)		
Number of Observations in Analysis		191		
Model R^2 value		0.2235		
Model F Statistic		14.67		
Model Significance (p-level)		0.0000		
	Unstandardized Coefficients	**Standard Error**	**T value**	**Significance (p-level)**
(Constant)	484.8	7.480	64.82	0.0000
C_ FTEDen	26.64	8.625	3.088	0.0023
C_ BedDen	120.3	48.72	2.470	0.0144
C_MRIDen	8961	2989	2.998	0.0031
C_CDD	0.0227	0.0088	2.563	0.0112

Note:
- *The regression is a weighted ordinary least squares regression, weighted by the Survey Weights (refer to Survey Weights Section)*
- *The prefix C_ on each variable indicates that it is centered. The centered variable is equal to difference between the actual value and the observed mean. The observed mean values are presented in **Table 2**.*
- *Full variable names and definitions are presented in **Table 2.***

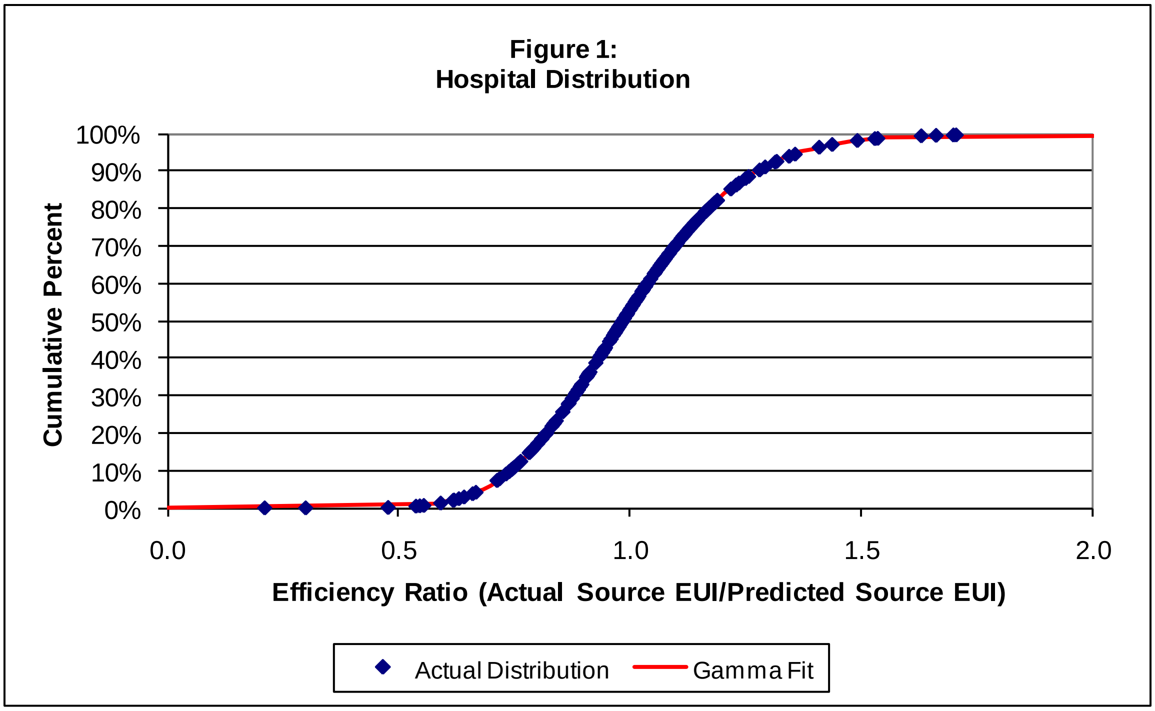
Hospital Lookup Table

The final regression model (presented in **Table 3**) yields a prediction of source EUI based on a building's operating constraints. Some buildings in the Hospital survey sample use more energy than predicted by the regression equation, while others use less. The *actual* source EUI of each survey observation is divided by its *predicted* source EUI to calculate an energy efficiency ratio:

Energy Efficiency Ratio = Actual Source EUI / Predicted Source EUI

A lower efficiency ratio indicates that a building uses less energy than predicted, and consequently is more efficient. A higher efficiency ratio indicates the opposite.

The efficiency ratios are sorted from smallest to largest and the cumulative percent of the population at each ratio is computed using the individual survey weights (described above). **Figure 1** presents a plot of this cumulative distribution. A smooth curve (shown in red) is fitted to the data using a two parameter gamma distribution. The fit is performed in order to minimize the sum of squared differences between each building's actual percent rank in the population and each building's percent rank with the gamma solution. For the Hospital model, an extra constraint was added to the gamma fit that required the fitted data to match the actual data at a score of 90 (cumulative probability of 0.1). This was done because the unconstrained fit did not match the data well for values above 90. The final fit for the gamma curve yielded a shape parameter (alpha) of 22.8952 and a scale parameter (beta) of 0.0437. For this fit, the sum of the squared error is 0.2434.



The final gamma shape and scale parameters are then used to calculate the efficiency ratio at each percentile (1 to 100) along the curve. For example, the ratio on the gamma curve at 1% corresponds to a rating of 99; only 1% of the population has a ratio this small or smaller. The ratio on the gamma curve at the value of 25% will correspond to the ratio for a rating of 75; only 25% of the population has ratios this small or smaller. The complete lookup table is presented at the end of the document. In order to read this lookup table, note that if the ratio is less than 0.5793, the rating for that building should be 100. If the ratio is greater than or equal to 0.5793 and less than 0.6196 the rating for the building should be 99, etc.

Example Calculation

As detailed in the document *Energy Performance Ratings – Technical Methodology*, there are five steps to compute a rating. The following is a specific example with the Hospital model:

<u>Step 1 – User enters building data into Portfolio Manager</u>

For the purposes of this example, sample data is provided.

- Energy data
  - Total annual electricity = 10,500,000 kWh
  - Total annual natural gas = 450,000 therms
  - Note that this data is actually entered in monthly meter entries
- Operational data
  - Gross floor area (ft^2) = 400,000
  - Full Time Equivalent Workers = 1200
  - Number of Staffed Beds = 220
  - Number of MRI Machines = 1

- CDD (provided by Portfolio Manager, based on zip code) = 1300

Step 2 – Portfolio Manager computes the Actual Source Energy Use Intensity

In order to compute actual source EUI, Portfolio Manager must convert each fuel from the specified units (e.g. kWh) into Site kBtu, and must convert from Site kBtu to Source kBtu.

- Convert the meter data entries into site kBtu
  - Electricity: (10,500,000 kWh)*(3.412kBtu/kWh) = 35,826,000 kBtu Site
  - Natural gas: (450,000 therms)*(100kBtu/therm) = 45,000,000 kBtu Site
- Apply the source-site ratios to compute the source energy
  - Electricity:
    35,826,000 Site kBtu*(3.34 Source kBtu/Site kBtu) = 119,658,840 kBtu Source
  - Natural Gas:
    45,000,000 Site kBtu *(1.047 Source kBtu/Site kBtu) = 47,115,000 kBtu Source
- Combine source kBtu across all fuels
  - 119,658,840 kBtu + 47,115,000 kBtu = 166,773,840 kBtu
- Divide total source energy by gross floor area
  - Source EUI = 166,773,840 kBtu/400,000 ft^2 = 416.9 kBtu/ft^2

Step 3 – Portfolio Manager computes the Predicted Source Energy Intensity

Portfolio Manager uses the building data entered under Step 1 to compute centered values for each operating parameter. These centered values are entered into the Hospital regression equation to obtain a predicted source EUI.

- Calculate centered variables
  - Use the operating characteristic values to compute each variable in the model. (e.g. FTEDen = 1200 / 400,000 * 1000 = 3.000)
  - Subtract the reference centering value from calculated variable
    (e.g. FTEDen – 2.600 = 3.000 – 2.600 = 0.400)
  - These calculations are summarized in **Table 4**
- Compute predicted source energy use intensity
  - Multiply each centered variable by the corresponding coefficient in the model (e.g. Coefficient*CenteredFTEDen = 26.64*0.400 = 10.66)
  - Take the sum of these products (i.e. coefficient*CenteredVariable) and add to the constant (this yields a predicted Source EUI of 498.4 kBtu/ft^2)
  - This calculation is summarized in **Table 5**

Step 4 – Portfolio Manager computes the energy efficiency ratio

The energy efficiency ratio is equal to: Actual Source EUI/ Predicted Source EUI.

- Ratio = 416.9/498.4 = 0.8365

Step 5 – Portfolio Manager looks up the efficiency ratio in the lookup table

Starting at 100 and working down, Portfolio Manager searches the lookup table for the first ratio value that is larger than the computed ratio for the building.

- A ratio of 0.8365 is less than 0.8411 (requirement for 77) but greater than 0.8349 (requirement for 78)
- ***The rating is78***

Table 4 **Example Calculation – Computing Building Centered Variables**				
Operating Characteristic	Formula to Compute Variable	Building Variable Value	Reference Centering Value	Building Centered Variable (Variable Value - Center Value)
FTEDen	FTE/ft^2*1000	3.000	2.600	0.400
BedDen	BED/ft^2*1000	0.5500	0.4636	0.0864
MRIDen	MRI/ft2*1000	0.0025	0.0031	-0.0006
CDD	CDD	1300	1392	-92
Note - *Densities are always expressed as the number per 1,000 square feet.* - *The center reference values are the weighted mean values from the survey, show in Table 2.*				

Table 5 **Example Calculation – Computing predicted Source EUI**			
Operating Characteristic	Centered Variable	Coefficient	Coefficient * Centered Variable
Constant	NA	484.8	484.8
FTEDen	0.400	26.64	10.66
BedDen	0.0864	120.3	10.39
MRIDen	-0.0006	8961	-5.377
CDD	-92	0.0227	-2.088
		Predicted Source EUI (kBtu/ft^2)	***498.4***

Attachment

Table 6 lists the energy efficiency ratio cut-off point for each rating, from 1 to 100.

Table 6
Lookup Table for Hospital Rating

Rating	Cumulative Percent	Energy Efficiency Ratio		Rating	Cumulative Percent	Energy Efficiency Ratio	
		>=	<			>=	<
100	0%	0.0000	0.5793	50	50%	0.9866	0.9918
99	1%	0.5793	0.6196	49	51%	0.9918	0.9970
98	2%	0.6196	0.6461	48	52%	0.9970	1.0023
97	3%	0.6461	0.6666	47	53%	1.0023	1.0076
96	4%	0.6666	0.6836	46	54%	1.0076	1.0129
95	5%	0.6836	0.6982	45	55%	1.0129	1.0182
94	6%	0.6982	0.7113	44	56%	1.0182	1.0236
93	7%	0.7113	0.7231	43	57%	1.0236	1.0290
92	8%	0.7231	0.7340	42	58%	1.0290	1.0345
91	9%	0.7340	0.7441	41	59%	1.0345	1.0401
90	10%	0.7441	0.7536	40	60%	1.0401	1.0457
89	11%	0.7536	0.7625	39	61%	1.0457	1.0513
88	12%	0.7625	0.7710	38	62%	1.0513	1.0570
87	13%	0.7710	0.7791	37	63%	1.0570	1.0628
86	14%	0.7791	0.7869	36	64%	1.0628	1.0687
85	15%	0.7869	0.7944	35	65%	1.0687	1.0746
84	16%	0.7944	0.8017	34	66%	1.0746	1.0807
83	17%	0.8017	0.8087	33	67%	1.0807	1.0868
82	18%	0.8087	0.8155	32	68%	1.0868	1.0930
81	19%	0.8155	0.8221	31	69%	1.0930	1.0994
80	20%	0.8221	0.8286	30	70%	1.0994	1.1059
79	21%	0.8286	0.8349	29	71%	1.1059	1.1125
78	22%	0.8349	0.8411	28	72%	1.1125	1.1192
77	23%	0.8411	0.8472	27	73%	1.1192	1.1261
76	24%	0.8472	0.8532	26	74%	1.1261	1.1332
75	25%	0.8532	0.8591	25	75%	1.1332	1.1404
74	26%	0.8591	0.8649	24	76%	1.1404	1.1479
73	27%	0.8649	0.8706	23	77%	1.1479	1.1556
72	28%	0.8706	0.8762	22	78%	1.1556	1.1635
71	29%	0.8762	0.8818	21	79%	1.1635	1.1716
70	30%	0.8818	0.8873	20	80%	1.1716	1.1801
69	31%	0.8873	0.8927	19	81%	1.1801	1.1888
68	32%	0.8927	0.8981	18	82%	1.1888	1.1980
67	33%	0.8981	0.9035	17	83%	1.1980	1.2075
66	34%	0.9035	0.9088	16	84%	1.2075	1.2175
65	35%	0.9088	0.9141	15	85%	1.2175	1.2280
64	36%	0.9141	0.9193	14	86%	1.2280	1.2391
63	37%	0.9193	0.9246	13	87%	1.2391	1.2508
62	38%	0.9246	0.9298	12	88%	1.2508	1.2634
61	39%	0.9298	0.9349	11	89%	1.2634	1.2768
60	40%	0.9349	0.9401	10	90%	1.2768	1.2915
59	41%	0.9401	0.9453	9	91%	1.2915	1.3075
58	42%	0.9453	0.9504	8	92%	1.3075	1.3252
57	43%	0.9504	0.9556	7	93%	1.3252	1.3452
56	44%	0.9556	0.9607	6	94%	1.3452	1.3683
55	45%	0.9607	0.9659	5	95%	1.3683	1.3957
54	46%	0.9659	0.9710	4	96%	1.3957	1.4298
53	47%	0.9710	0.9762	3	97%	1.4298	1.4761
52	48%	0.9762	0.9814	2	98%	1.4761	1.5510
51	49%	0.9814	0.9866	1	99%	1.5510	NA